REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

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1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
03-02-2014	Final Report	15-Oct-2011 - 14-Jul-2012

4. TITLE AND SUBTITLE
Final Report

5a. CONTRACT NUMBER
W911NF-11-1-0323

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
611102

6. AUTHORS
James Damon

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES
University of North Carolina - Chapel Hill
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104 Airport Drive, Suite 2200, CB #1350
Chapel Hill, NC 27599 -1350

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSOR/MONITOR'S ACRONYM(S)
ARO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
60387-MA-II.1

12. DISTRIBUTION AVAILIBILITY STATEMENT
Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT

In this research the investigator proposed to examine the physical properties of plant root systems and determine how well they can be modeled using the intake capacity distributions with respect to two physically important distances, the depth and the radial distance from the vertical center line.

This analysis required the construction of 3D piecewise linear models from multiple images from different directions, and at different stages of growth. These models would

15. SUBJECT TERMS
Plant Root Structure, models constructed from multiple images

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			James Damon
UU	UU	UU	UU		19b. TELEPHONE NUMBER 919-962-9617

Report Title

Final Report

ABSTRACT

In this research the investigator proposed to examine the physical properties of plant root systems and determine how well they can be modeled using the intake capacity distributions with respect to two physically important distances, the depth and the radial distance from the vertical center line.

This analysis required the construction of 3D piecewise linear models from multiple images from different directions, and at different stages of growth. These models would have ideally been made for multiple plants of a given species, and across a number of species. Then, basic computations, obtained with improved software the investigator had already applied to several preliminary examples, could be applied to the models and compared with theoretical results.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

None to report

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Paper

TOTAL:

Patents Submitted

Patents Awarded

Awards

Simons Fellow

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
James Damon	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED	Discipline
Marshall Lochbaum (received pay	1.00	Computer and Computational Sciences
Bihan Zhang (received pay for wo	1.00	Computer and Computational Sciences
FTE Equivalent:	**2.00**	
Total Number:	**2**	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:..... 0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME	
Ellen Gasparovic	percent(0)
Joel Pereira	percent(0)
Total Number:	**2**

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Computer Science, Marshall Lochbaum and Bihan Zhang, undertook to construct from plant root images a 3D piecewise smooth model for the plant root system with the additional data of varying cross-sectional area of the roots. The resulting geometric and physical properties of the plant root system would then be compared, using programs which the investigator had previously written, with several theoretical models involving the intake capacity distributions with respect to depth and the radial distance from the vertical center line. In particular, certain properties the investigator had observed in several cases he had analyzed by hand, would be compared with results for a time series for a single plant root system, and further compared with results for multiple plants of the same species and across a number of species.

The construction of the 3D model is derived from a collection of 20 images at successive 18 degree angles about a central vertical axis. The approach to construct the model was a two step process where first a 3D volumetric model would be constructed, and then a piecewise smooth model with cross-sectional data would be constructed from the volumetric model.

The investigator consulted with Gary Bishop and Leonard McMillan who both contributed to the development of the “visual hull method” for reconstructing a 3D object from multiple projections. They pointed him to a library of software by Matusik for implementing the method. After performing several alignment procedures to the images, it was discovered that experimental method for capturing the images did not include accurate “camera calibration” which is a basic ingredient for the most effective use of the software. This forced a basic reevaluation of how to apply the method and compensate for this gap. Also, the visual hull method is especially effective for objects that are largely convex; however, the many roots in the plant root image produced a considerable amount of noise, which made the resulting volumetric model of limited use. Much effort went into trying methods to overcome these problems. These included attempts to identify from among the images a subset which minimized noise. A second method was applied which employed a Markov Chain Monte Carlo method for sampling the 3D viewspace for points in multiple images to construct a probabilistic distribution for the 3D volumetric model. This was to be combined with a section method for identifying at identified root points an elliptical cross-sectional model, which together with root direction would give an orthogonal cross-section.

Various parts of this process were implemented in code written in either Matlab, or the language “J”. The work still had not reached the point where it was possible to identify all of the roots in the image without introducing by the user additional seed points for the method. Also, only preliminary steps were taken to move from the probabilistic model of point densities to obtain an accurate volumetric model. There then remained the issue of constructing the piecewise linear model central to the volumetric one and using the elliptical cross-section to complete the model.

TIme became an important limiting factor in the project because of the delay in obtaining the computer on which was loaded the images, compilers and software which we used. The grant began at the end of October, with the computer being ordered then; however, the Purchasing Dept. at UNC did not deliver the computer until early December, at which time the undergraduates were starting their final exams, followed by the Christmas vacation. This meant that except for some preliminary discussions, the work did not really begin until January, and continued until roughly mid May, when the academic year ended and the students left for summer jobs.

The investigator had hoped that the project would have been further enough along by June so that he could continue using what had been developed to begin analyzing the variety of root images and testing the results against the theoretical ideas. Because this was not possible, the investigator asked that almost all of the funds from the grant ($44,793 of the original grant award $50,000) be de-obligated It was intended to reapply for a STIR grant for the next academic year requesting the remaining funds to continue with the project. Because the investigator received a University leave to be away the next academic year, the reapplication was postponed, but has not been abandoned.

Technology Transfer

FInal Report for ARO STIR Grant 60387-MA-II

"Comparing Mathematical Models and Experimental Data for Intake Capacity Distributions for Plant Root Structures"

In this "STIR" grant, this investigator with two undergraduate students in Computer Science, Marshall Lochbaum and Bihan Zhang, undertook to construct from plant root images a 3D piecewise smooth model for the plant root system with the additional data of varying cross-sectional area of the roots. The resulting geometric and physical properties of the plant root system would then be compared, using programs which the investigator had previously written, with several theoretical models involving the intake capacity distributions with respect to depth and the radial distance from the vertical center line. In particular, certain properties the investigator had observed in several cases he had analyzed by hand, would be compared with results for a time series for a single plant root system, and further compared with results for multiple plants of the same species and across a number of species.

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